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MOTION SICKNESS SYMPTOMATOLOGY OF LABYRINTHINE DEFECTIVE AND NORMAL SUBJECTS DURING ZERO GRAVITY MANEUVERS

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FOREWORD

This report was prepared jointly by the Human Engineering Division, Behavioral Sciences Laboratory, 6570th Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio, and the U. S. Naval School of Aviation Medicine, U. S. Naval Aviation Medical Center-54, Pensacola, Florida. The report represents one phase of the research program being conducted by the Crew Stations Branch of the 6570th Aerospace Medical Research Laboratories, under Project No. 7184, "Human Performance in Advanced Systems," Task No. 718405, "Design Criteria for Crew Stations in Advanced Systems." The research was conducted under the sponsorship of the Office of Life Science Programs, National Aeronautics and Space Administration (Grant R-47).

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ABSTRACT

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Labyrinthine defective (L-D) and normal subjects were flown through zero-gravity maneuvers and their motion sickness symptomatology observed. The L-D subjects showed no signs of motion sickness, whereas 64 percent of the normal subjects developed symptoms. The absence of functional labyrinthine mechanisms appreciably decreased, and probably completely eliminated, susceptibility to motion sickness during zero-gravity maneuvers.

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PUBLICATION REVIEW

This technical documentary report is approved.

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INTRODUCTION

The primary objective of this investigation was to compare the functional symptoms of two groups of subjects during exposure to the force environment in a C-131B aircraft flying through standardized Keplerian trajectories. One group of subjects was made up of persons with bilateral labyrinthine defects (L-D), while a second group had normal vestibular function (normal subjects). A secondary objective was to compare the findings obtained in this environment with those obtained earlier on some of the same subjects exposed to standardized acrobatics, wave action at sea (ref 6), coriolis acceleration in a slowly rotating room*, and centripetal force in a counterrotating room (ref 5).

A survey of the pertinent literature has not disclosed any report dealing with exposure of L-D subjects to weightlessness. There are a few reports describing their participation in other types of experimental flights, but no comment was made regarding symptoms of motion sickness (refs 7,9).

Persons with normal vestibular function have been exposed to weightlessness in a variety of experiments. The experiment which has been used most extensively is the parabolic flight which produces weightlessness periods of 10 to 60 seconds, preceded and followed by high positive-G loads. In these flights, subjects were either "restrained" (refs 3,16) or "free floating" (ref 8). Gerathewohl (ref 3) has summarized his experience at the USAF School of Aviation Medicine in which 16 subjects were exposed to a total of 300 parabolas, during which 6 of the subjects developed motion sickness. Von Beckh (ref 1), summarizing the experience at Holloman Air Force Base, reported that 6 of 18 subjects became motion sick during zero-gravity flights in a T-33 jet aircraft. Loftus (ref 8) has summarized the extensive experience of two groups of subjects at Wright-Patterson Air Force Base. In the first group, 45 persons participated in zero-G flights and 23 vomited on one or more flights. In the second group, 90 persons participated, 21 vomited and 23 others reported nausea. Of the total of 44 who vomited, 60% experienced a recurrence of nausea in the evening of the day they were motion sick.

Three generalizations may be drawn from these experiences with parabolic flights: (1) the incidence of motion sickness was greater when subjects were "free floating" as compared with being "restrained," (2) susceptibility to motion sickness is generally lower with increased flight experience, and (3) weightlessness was not the only variable and the motion sickness produced may have been influenced by the other flight stresses, particularly the positive G's.

More prolonged exposures to weightlessness have been experienced in other types of flights; namely, the X-15 (ref 12), the suborbital, and the orbital flights.

*Graybiel, A., and Clark, B. A report on a comparison of the symptoms experienced by healthy persons and subjects with labyrinthine defects exposed to Coriolis acceleration in a rotating environment. In preparation at the Naval School of Aviation Medicine, Pensacola, Florida.

From the information available, only Cosmonaut Titov (refs 2,13,14) experienced symptoms characteristic of motion sickness. The fact that Glenn (ref 4) reported slight seasicknesses while in a life raft after impact points up the lack of transfer from whatever adaptation to unusual force environments he acquired in flying to the environment at sea.

METHODOLOGY

Subjects

The 6 L-D subjects tested ranged in age from 20 to 48 years. The principal clinical findings on these subjects are summarized in Table I. The tests of otolith function revealed sufficient variance to raise the question of residual function in some instances.

The 19 normal subjects were made up of two groups, student subjects and regular subjects. The former consisted of 9 healthy medical students, 21 to 25 years old. A 10th candidate was not allowed to participate because his susceptibility to motion sickness under other circumstances indicated undesirable complications might ensue. The regular subjects consisted of 10 enlisted men, 18 to 21 years old, who were assigned to the Naval School of Aviation Medicine for the express purpose of participating in experiments. All 19 subjects were free of functional disorder, defect or disease of the sensory organs of the inner ear as determined by history, audiogram, and the caloric test.

The Force Environment

Reference 18 describes in detail the force environment of the zero-gravity airplane. A typical flight procedure, for convenience termed a "maneuver," consisted of a shallow dive followed by a pullup generating 2.5 G and a pushover into a ballistic trajectory with approximately 10 to 12 seconds of weightlessness. Recovery involved a pullup generating about 2.5 G. Unless interrupted, a flight sequence consisted of 40 maneuvers.

Procedure

The subjects were thoroughly briefed regarding the nature of the experiment and were indoctrinated in safety procedures. They were seated in airline-type seats and restrained by seat belts. The information sought was obtained with the aid of four questionnaires. The first questionnaire dealt with the fitness of the subject to participate and with his estimate of his concern and expected performance in relation to others. The second questionnaire was used by the experimenter and consisted of a checkoff list with rating scales of the signs and symptoms of motion sickness. The third and fourth questionnaires were used to assist the subject and experimenter in the final evaluation immediately after the flight.

Table I

Clinical Findings and Results of Functional Tests of Auricular Organs of Six Subjects with Labyrinthine Defects

Subject	Age	Etiology	Age of Onset	History of Motion Sickness	Hearing Threshold R	Hearing Threshold L	Caloric Test R	Caloric Test L	Counterrolling Index (min. of arc)
A	20	Meningitis	12-1/2 yrs.	Car, bus*	130db	135db	[1]Neg	[1]Neg	117
B	21	Meningitis	4-1/2 yrs.	None	145db	145db	[2]Neg	[3]Neg	89
C	20	Meningitis	3-1/2 yrs.	None	135db	130db	None	None	36
D	25	Meningitis	8 yrs.	None	None	None	None	None	82
E	22	Meningitis	3 yrs.	None	None	None	None	None	85
F	48	Mastoidectomy	12 yrs	None	None	160db	None	None	90

* Slight nausea: "occasionally long trips"

No vertigo or observable nystagmus when tympanum irrigated with cold water (4.5° to 6°C). Numerals refer to nystagmograms obtained during irrigation with cold water for three minutes: 1. questionable vertical nystagmus, 2. questionable nystagmus, 3. minimal nystagmus.

Normal range (9 subjects) 286 to 465

As indicated in table II, only two symptoms were reported for the entire group of L-D subjects and these symptoms were barely detectable. The L-D's as a group were essentially symptom free. They enjoyed the flight and grasped every opportunity to fly as an assistant or passenger. In these additional flights they appeared to enjoy the experience of free-floating.

The normal subjects were ranked in order of decreasing susceptibility to the functional symptoms of motion sickness. Four of the 10 regular subjects (table III) were regarded by the experimenter as less fit than normal although they rated themselves as "fit." All except one regular subject completed the series of 40 maneuvers. This subject requested termination because of severe discomfort. There were individual differences among the regular subjects but these differences were not predictable from their own estimate of concern or performance. Of particular interest were the effects in the case of L whose verbatim report follows:

"Immediately after the flight, I noticed no unordinary aftereffects except a little difficulty walking and a slight nausea. This lasted for about an hour after the flight. Everything was fine until late Friday (day of flight) night. At approximately 10:45, I noticed difficulty in walking when I was getting ready to turn in. (Since about 8, I was watching TV and noticed nothing.) Whenever I would take a step, my foot would seem to keep falling. When I lay in my bed I seemed to be tossing from side to side. I know I wasn't because I was holding on to my bed. Several times I got out of bed and walked to the bathroom and while in the bathroom would walk up and down seeing if it would stop. It would stop for a while and start up again. I went to sleep, and when I woke up I felt normal until approximately 10 when it started again. I noticed it the most when I would come from one extreme to the other, ie, from very bright light to a place of shade, from a warm space into a cold space or vice-versa, or when I would stand up rapidly. Saturday, around noon, I went to town, and it seemed to get worse. When I would sit down, it would have a strong effect. This lasted until that (Saturday) night, varying from a point of strong effect to a weak one, and at times it would disappear entirely. When going to sleep Saturday night, I felt fine. Sunday morning I noticed it very slightly every once in a while, then it seemed to clear up completely. Today, Monday, I have no feelings of unstableness at all. 10:30."

Careful inquiry revealed no explanation for the symptoms in terms of medical history or associated symptomatology. Subsequently, this subject participated in a series of flights in which he was exposed to even longer periods of weightlessness without delayed aftereffects. This incident points up a troublesome deviation from the usual pattern of vestibular sickness.

The student subjects (table IV) also varied greatly in susceptibility but differed from the regular group in that more fell at one extreme or the other. One flight sequence was terminated after ten maneuvers at the request of two subjects. One of the two subjects, Q, felt sick after one maneuver, and both subjects manifested symptoms of anxiety, suggesting that the flight acted in part as a nonspecific stressor. Two other subjects who were on the same flight necessarily failed to

Table II

Findings in Six Subjects With Labyrinthine Defects
Exposed to Weightlessness in Parabolic Flights

Subject	Subject's Estimate of Fitness	Observer's Estimate of Fitness	Subject's Estimate of Concern (1)	Subject's Estimate of Performance (2)	Symptoms of Anxiety	Experiment Completed	Vomit (No. X)	Retch (No. X)	Nausea (1)	Sweat (1)	Pallor (1)	Restrict Movement	General Discomfort (1)	Other Symptoms	Recovery
A	Yes	Slightly Less	I	Av+	0	Yes	0	0	0	0	0	No	I	0	Not Applicable
B	Yes	Yes	I	Av+	0	Yes	0	0	0	0	0	No	0	0	Not Applicable
C	Yes	Yes	I	Av+	0	Yes	0	0	0	0	0	No	0	0	Not Applicable
D	Yes	Yes	I	Av+	0	Yes	0	0	0	I	0	No	0	0	Not Applicable
E	Yes	Yes	I	Av+	0	Yes	0	0	0	0	0	No	0	0	Not Applicable
F	Yes	Yes	I	Av+	0	Yes	0	0	0	0	0	No	0	0	Not Applicable

(1) Three-point scale, I = slight or minimal

(2) Av; above Av = Av+

* Expressed in terms of 'usual fitness"

Table III

Findings in Ten Regular Subjects Exposed to Weightlessness in Parabolic Flights

Subject	Age	Subject's Estimate of Fitness*	Observer's Estimate of Fitness	Subject's Estimate of Concern (1)	Subject's Estimate of Performance (2)	Experiment Completed	Symptoms of Anxiety (3)	Vomit (No. X)	Retch (No. X)	Nausea (1)	Sweat(1)	Pallor(1)	Restrict Movement	General Discomfort (1)	Other Symptoms (4)	Recovery
G	19	Yes	Yes	III	Av	No	1,3	1	I	III	II	II	Yes	III	1,2, 4,5,8	Slow
H	19	Yes	Slightly Less	II	Av	Yes	0	I	0	II	I		Yes	I	1,3	Rapid
I	19	Yes	Slightly Less	III	Av	Yes	1,3,5	0	I	I	I	II	Yes	I	1,2, 4,5,6	
J	20	Yes	Yes		Av	Yes	0	0	0	II	I	I	No	I	1	Rapid
K	19	Yes	Yes	II	Av	Yes	1	0	0	I	I	I	Yes	I	1,4.5	Rapid
L	18	Yes	Yes	III	Av	Yes	0	0	0	I	I	I	No	I	4	Delayed
M	18	Yes	Slightly Less	II	Av	Yes	0	0	0	I	I	I	No	I	0	Rapid
N	18	Yes	Slightly Less	III	Av	Yes	4	0	0	I	0	0	No	I	1,3,7	Fast Fatigued
O	20	Yes	Slightly Less	III	Av+	Yes	3	0	0	0	I	0	No	I	7	Not Applicable
P	21	Yes	Yes	III	Av-	Yes	0	0	0	0	I	0	No	I	0	Not Applicable

(1) Three-point scale, I = slight or minimal
(2) Av; above Av = Av+; below Av = Av-
(3) 1. Characteristics appear, 2. Frequent sighing, 3. Awareness of breathing, 4. Blurred vision, 5. Dry mouth
(4) 1. Stomach awareness, 2. Anorexia, 3. Drowsiness, 4. Dizziness, 5. Headache, 6. Yawn, 7. Includes salivation, 8. Desire bowel movement
* Terminated at subject's request

Expressed in terms of "usual fitness"

Table IV

Findings in Nine Student Subjects Exposed to Weightlessness in Parabolic Flights

Subject	Age	Subject's Estimate of Fitness *	Observer's Estimate of Fitness	Subject's Estimate of Concern (1)	Subject's Estimate of Performance (2)	Experiment Completed	Symptoms of Anxiety (3)	Vomit (No. X)	Retch (No. X)	Nausea(1)	Sweat(1)	Pallor(1)	Restrict Movement	General Discomfort (1)	Other Symptoms (4)	Recovery
Q	23	Yes	Yes	II	Av	No	1,2,5	I	I	III	II	II	Yes	III	1,2,3, 4,5,7	Slow
R	21	Yes	Yes	I	Av	No	1,2,3,5	0	0	III	II	II	No	III	1,2,4	Rapid
S	24	Yes	Yes	III	Av	Yes	3,5	0	0	I	I	I	No	I	1,3,6	Rapid
T	24	Yes	Slightly Less	II	Av	No	0	0	0	0	II	II	No	I	1,4	Rapid
U	25	Yes	Yes	I	Av	No	0	0	0	0	II	I	0	0	0	Rapid
V	22	Slightly Less	Slightly Less	I	Av	Yes	0	0	0	0	I	I	0	I	1,3	Rapid
W	21	Yes	Slightly Less	I	Av	Yes	0	0	0	0	II	0	No	0	0	Not Applicable
X	22	Yes	Yes	I	Av+	Yes	0	0	0	0	0	0	No	0	0	Not Applicable
Y	21	Yes	Yes	III	Av+	Yes	0	0	0	0	0	0	No	0	0	Not Applicable

(1) Three-point scale, I = slight or minimal
(2) Av; above Av = Av+
(3) 1. Characteristics appear, 2. Frequent sighing, 3. Awareness of breathing, 4. Blurred vision, 5. Dry mouth
(4) 1. Stomach awareness, 2. Anorexia, 3. Drowsiness, 4. Dizziness, 5. Headache, 6. Yawn, 7. Includes salivation, 8. Desire bowel movement
Terminated at subject's request
Expressed in terms of "usual fitness"

complete the predetermined number of maneuvers, but the early appearance of pallor and sweating suggested that they were to be included among those who were quite susceptible. At the other extreme were two "insusceptibles" who showed no symptoms of motion sickness.

The L-D subjects and the nine student subjects had been exposed to unusual force environments other than parabolic flight. A listing of the student subjects symptomatology is given in table V. Since the L-D subjects showed no symptoms in any of the force environments, these subjects are not included in the table. The student subjects, ranked in order of susceptibility to symptoms in the C-131 aircraft show the same general trend of susceptibility which occurred in the other force environments.

SUMMARY AND DISCUSSION

Subjects with bilateral vestibular defects not only failed to show or report symptoms of motion sickness in parabolic flight but actually enjoyed the experience. The likelihood of obtaining similar results in six normal persons with minimal flight experience is small. We assume the L-D subjects were representative of labyrinthine defective subjects in general and that loss of vestibular function in the L-D subjects was responsible for their lack of symptoms.

The incidence of symptoms in the normal subjects corresponds closely to the results reported by Loftus (ref 8). Although Loftus reported a 51% incidence of symptoms as compared to 54% in this study, he used vomiting as the only indicator of motion sickness. The percentages would very likely have been in even closer agreement if other symptoms had been considered.

Apparently symptoms such as the ones Titov experienced in orbital flight may be ascribed to vestibular function. That the other participants in orbital flight did not experience symptoms might have been due either (1) to low basic susceptibility, (2) to transfer of adaptation acquired in other types of flight or accelerative devices, (3) to the fact that weightlessness is not a strong precipitating factor, or (4) to a combination of these. Our findings indicate some persons are resistant to motion sickness when making transitions in and out of the weightless state, whereas the majority of naive persons with a normally functioning labyrinth are highly susceptible. Although there is some evidence that experienced pilots (ref 1) are resistant to vestibular sickness in weightlessness, there is little actual proof of transfer of adaptation. We believe if weightlessness is a factor in precipitating symptoms of motion sickness, it is not a strong factor.

Table V

Findings in Nine Student Subjects Exposed to Various Force Environments

Student Subject	Age	History of Motion Sickness	C-131[1]	AD5[2]	Sea[3]	SRR[4]	CRR[5]
Q	23	V	V	IV	IV	V	III
R	21	V	V	IV	V	IV	V
S	24	III	III	IV	Nil	V	II
T	24	V	III	III	III	V	IV
U	25	III	III	III	Nil	III	IV
V	22	Nil	I	II	Nil	II	I
W	21	Nil	Nil	Nil	Nil	I	-
X	22	Nil	Nil	II	I	I	Nil
Y	21	Nil	Nil	Nil	Nil	II	-

Five-point scale, I = slight or minimal

1. Zero-gravity flights
2. Standardized acrobatics for 30 minutes
3. Exposure in small boat
4. Exposure in slow-rotation room (ref 5), which stimulates the semicircular canals in an unusual pattern
5. Exposure in counter-rotating room (ref 6); absence of angular velocity permits avoidance of stimulation to the semicircular canals

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